Temperature, salinity and Plankton of Daman Ganga Estuary[1]

P. Sitaramaiah
Department of Biology, Govt. Arts and Science College, Daman

Temperature of air and water of Daman Ganga estuary showed two maxima in a year and the water was warmer than the Arabian sea. A wide range of values of salinity were associated with a wide range of values of biomass of plankton. The values of biomass of plankton of this estuary, at comparable salinity and temperature, were three times less compared to the Mississippi Sound. The values of biomass of plankton in winter were 2.3 times higher compared to the values of biomass of plankton in summer. A plankton calendar was prepared for this estuary for the year 1968-'69. An increase in the number of copepods was associated with an increase in the numbers of phytoplankton. Daman Ganga estuary is a special ecological habitat with warmer water and more numbers of microplankters compared to the adjoining Arabian sea. Warmer waters and abundant microplankton of this estuary are the favourable factors for the survival and rapid growth of planktophagous larvae of euryhaline marine fishes. Thus Daman Ganga estuary, with its special ecological conditions, forms one of the natural factors responsible for the good fish landings of this part of the west coast.

Introduction

Information is not available on the physicochemical and biological conditions of Daman Ganga estuary. Therefore, to find out the factors influencing the abundance of plankton, temperature of air and water, salinity, numbers and dry weights of plankton were studied for a period of 54 weeks. The interrelations of organisms and the influence of hydrographical conditions on the abundance of plankton were studied and compared with other areas.

Field collections were made, always at a fixed area, between 12.00 noon and 1.00 p.m. once in every week. The area of investigation is located at 20°25′ N, 72°50′ E. The width of the river at Daman is

[1] Accepted February 6, 1971.

224 metres excluding the banks. The depth of the river is 6 metres at the lowest low tide level and ten metres at the maximum high tide level.

Methods

Temperature of air and water were recorded in the field using a centigrade mercury thermometer graduated to one tenth of a degree. A sample of water was brought to the laboratory, in a clean glass stoppered bottle and the salinity was measured by Harvey's method (Barnes 1959). Ten ml of sample water was titrated against standard silver nitrate solution using potassium chromate as indicator. The necessary correction, as given by Harvey, was made. Three titrations were made and the average values are presented. Plankton collections were made concurrently with the hydrographical studies. Plankton was collected with half metre tow net made of best Swiss organdy. The net was towed by boat for 5 minutes across the river from bank to bank. Thus, a cross section of nearly 37 (36.83) cubic metres of water was filtered by the net, as a distance of 190 metres was constantly covered, in 5 minutes. The plankton collections were transferred to a pneumatic trough and the plankters were examined in fresh condition in the laboratory. The debris and other foreign materials were carefully hand-picked. The plankton was then filtered with the organdy and was washed in to 5% formalin kept in an enamel tray. Later the plankton was transferred in to a bottle. Macro-plankton and nekton were separated and 1 ml of sample was diluted to a constant volume. From this diluted sample 1 ml was taken in to a Sedgwick Rafter cell and the numbers of plankters were counted under a microscope. Six counts were made for each plankton sample and the average numbers of organisms are presented. Later the plankton was filtered using Whatman No. 42 filter paper (Graham 1943) and dried in a hot air oven at 60°C to constant weight. The average values for each month are presented.

Results

(1) **Temperature:**

The results of air temperature are presented (Table 1). The temperature maxima (35.2°C) was recorded on 7-iv-1969. The temperature minima (22.8°C) was recorded on 4-i-1969. The submaximum temperature (35°C) was recorded on 30-ix-1969 and also in the first two weeks and fourth week of October, 1969. The amplitude of annual variation of daily temperatures was 12.4°C. The amplitude of variation of mean monthly temperatures was 7.44°C. The mean

monthly temperature showed two maxima one in April and the other in October.

Table 1

Temperature of Daman Ganga estuary during 1968-'69

Month & Year	Temperature of Air °C		Temperature of Water °C	
	Range	Average	Range	Average
Nov. 1968	30.0-34.40	32.14	27.0-30.0	28.16
Dec.	29.4-32.00	31.00	25.2-28.4	26.60
Jan. 1969	22.8-30.00	26.60	22.0-25.6	24.08
Feb.	27.0-33.10	29.27	25.0-26.4	25.70
Mar.	28.9-32.80	30.58	27.0-31.0	29.10
Apr.	31.4-35.20	33.20	31.4-32.9	32.17
May	32.0-33.20	32.65	32.0-33.0	32.65
June	28.8-32.40	30.65	29.0-32.2	31.25
July	29.4-31.20	30.56	29.0-32.2	30.44
Aug.	29.4-32.80	30.55	28.6-31.9	30.07
Sep.	27.0-35.00	30.08	26.6-33.2	29.60
Oct.	30.4-35.00	34.04	29.8-31.8	30.72

The results of water temperature are also presented in Table 1. The temperature showed variation in each month. Maximum temperature (33.2°C) was recorded on 30-ix-1969 and minimum (22.0°C) was recorded on 1-i-1969 and on 4-i-1969. The amplitude of annual variation of daily temperature was 11.2°C. The amplitude of annual variation of mean monthly temperatures was 8.57°C. The temperature of water showed two maxima which were recorded in May and October, 1969. The air and water temperatures of this estuary showed two maxima in the year.

In Daman Ganga estuary mean monthly water temperatures ranged from 24.08°C to 32.65°C. Chacko & Ganapati (1949) recorded highest temperatures in April and May and lowest temperatures during December and January with an annual range of 22.0° - 35.0°C in Adayar estuary. Ganapati & Murthy (1955) reported three peaks in temperature in October, March and June and three depressions in January, April and August with an annual range of monthly mean temperature of 4.4°C in the sea off Visakhapatnam coast. Bose (1956) reported a temperature range of 18.0 - 33.0°C in Hooghly estuary. The temperatures of the water of this estuary are higher compared to the sea water temperatures of Arabian sea off this estuary at 20°N and 21°N (Jayaraman & Gogate 1957) by 2.3°C (December), 1.58°C (January), 2.2°C (February) and 3.6°C (March). Ganapati & Sarma (1958) recorded a variation of temperature of 24.33 - 29.9°C in sea at Waltair with two peaks in June and September (1953-1954) and June and October (1954-1955). Subrahmanyan (1960a) recorded at Calicut

25.3°C (July) and 30.0°C (April). But in this estuary 30.44°C and 32.17°C were recorded in the respective months thereby indicating that the temperature of the estuarine waters of Daman Ganga were 5.14°C and 2.17°C higher compared to sea water at Calicut. The occurrence of two peaks was reported for all the warmer areas in and around India by several workers (Sitaramaiah 1966b). Durve & Bal (1961) reported lowest temperatures during November-December and highest temperatures during April-May in backwater and sea water respectively near Bombay. Panikkar & Jayaraman (1966) have reported 27-29°C in Bay of Bengal and 23-29°C in Arabian sea. Qasim *et al.* (1969) recorded 28-31°C in a tropical estuary.

The temperatures of Daman Ganga estuary were higher by a minimum of 1.58°C (January) and ranged to a maximum of 5.14°C (July) compared to the adjacent Arabian sea. Malhotra *et al.* (1970) reported higher percentage (25-80% and 15-30%) of hatching of fertilized eggs of *Hilsa ilisha* at higher temperature ranges (25.5 - 30.4°C and 26.8 - 28.4°C) and low percentage (5-20% except in one case of 70%) at lower range of temperatures (24.8-27.1°C). Thus, it is clear that with its warmer water Daman Ganga estuary forms a good breeding ground for the fishes to spawn (Table 5) and a natural nursery for the hatching and development of eggs of euryhaline fishes.

(2) **Salinity:**

The results of salinity are presented in Table 2. The salinity of this estuary varied from 0.36‰ (on 17-vii-1969 and on 24-vii-1969) to 34.3‰ (on 18-i-1969). During the period November 1968 through June 1969 the mean monthly salinities varied from 28.62‰ to 33.27‰. The amplitude of annual variation of mean monthly salinities was 31.92‰. During the period July 1969 to October 1969 the mean monthly salinities varied from 1.35‰ to 19.82‰. Thus, the salinities of this estuary touch both the extremes with two distinct and widely separated ranges. The high and low salinities of this estuary were due to the maximum influx of sea water into the estuary and the rainfall in the upper reaches of the river respectively.

Ganapati & Murthy (1955) reported minimum salinity in November in the sea at Visakhapatnam while in this study the mean monthly minima was recorded in August. Bose (1956) reported a salinity range of 1.6‰ to 30.0‰ in Hooghly estuary. In the present study highest salinity was recorded in January (34.3‰) and the mean monthly maxima was recorded in February 1969, while Ganapati & Sarma (1958) recorded, maxima in April, in the sea off Waltair coast. Jayaraman & Gogate (1957) have recorded, off this estuary in Arabian sea, at 20°N, a salinity of 32.65‰ (November) to 36.02‰ (December to May) and at 21°N salinity of 36.45‰ (June), 36.76‰ (August), 33.55‰ (November) and 36.0‰ (May). Ramamoorthy's (1953b)

Table 2

Tide, colour of water and salinity of Daman Ganga estuary during 1968-'69

Month & Year	Tide	Colour of water	Salinity ‰ Range	Average	Remarks
Nov. 1968	HHHHL	Blue	26.34-33.50	30.31	
Dec.	HHHL	Brownish green	27.22-31.65	29.81	Bloom
Jan. 1969	HHHLL	Blue	16.23-34.30	28.62	Bloom
Feb.	HHLL	Blue	32.70-33.50	33.27	
Mar.	HHHLL	Blue	30.18-33.50	32.05	
Apr.	HHHL	Blue	30.51-33.30	32.05	Bloom
May	HHHH	Blue	31.58-31.11	31.71	Bloom
Jun.	HHHL	Blue	26.72-31.15	29.64	
July	HHHLL	Muddy brown	00.36-07.36	02.37	
Aug.	HHHL	Muddy brown	00.90-02.70	01.35	
Sep.	HHHLL	Muddy brown	00.72-08.52	03.92	Bloom
Oct.	HHHLL	Blue	06.70-27.78	19.82	

results of Madras coast are similar to those of Jayaraman (Subrahmanyan 1960a) and vary between 23.23‰ to 34.94‰. Panikkar & Jayaraman (1966) have reported 30.33‰ in Bay of Bengal and 34.37‰ in Arabian sea. Qasim *et al.* (1969) recorded 2.2‰ in a tropical estuary.

(3) **Biomass of Plankton:**

The results of dry weights of plankton are presented in Table 3. The dry weights of plankton varied from 0.001 to 16.575 gm. The values of biomass closely followed the salinity values. A salinity range of 0.36‰ to 8.52‰ from 3-vii-1969 to 7-x-1969 was associated with an average biomass of plankton of 0.063 gm for 5 minutes per collection. The total number of plankters was also very low in the very low salinity range (Tables 3 & 4). A salinity range of 23.93‰ to 34.3‰ (except 16.23‰ on 25-i-1969 and 13.71‰ on 18-x-1969) from 2-xi-1968 to 28-vi-1969 and from 11-x-1969 to 31-x-1969 was associated with an average biomass of plankton of 0.796 gm for 5 minutes per collection. The biomass of plankton at low salinity was twelve and half times less compared to the biomass values of plankton at high salinity ranges. The ranges of temperatures, corresponding to the higher and lower salinity ranges, were 22.0-33.0°C and 26.6 to 33.2°C respectively.

Sitaramaiah (1967a) reported rich amounts of plankton, nekton and shrimps at higher salinity ranges in Mississippi Sound. In Mississippi Sound a high salinity range of 18.02‰ to 27.75‰ at Deer Island station and a low salinity range of 12.9‰ to 24.0‰ at station 28 were associated with an average production of plankton of 2.423 gm and 2.371 gm for 5 minutes per collection respectively. In Mississippi

TABLE 3

NUMBERS AND DRY WEIGHTS OF PLANKTON OF DAMAN GANGA ESTUARY DURING 1968-'69

Month & Year	Number/5 Minutes Thousands Range	Average	Dry Weights/5 Minutes gm Range	Average
Nov. 1968	0.368-37.09	8.699	0.002-0.037	0.014
Dec.	4.682-138000	34542.83	0.001-2.39	0.62
Jan. 1969	7.034-327.291	80.443	0.02 -0.25	0.074
Feb.	0.341-25.893	7.981	0.001-1.435	0.394
Mar.	0.14 -95.788	29.075	0.001-0.86	0.245
Apr.	0.313-476.8	122.979	0.11 -0.34	0.207
May	5.718-3629.3	1612.25	0.18 -3.065	1.446
Jun.	0.011-14.5	6.823	0.001-1.36	0.399
Jul.	0.003-3.192	0.7	0.001-0.655	0.132
Aug.	0.001-0.31	0.119	0.001-0.11	0.028
Sep.	2.643-1592.43	319.66	0.005-0.215	0.045
Oct.	0.842-120.14	41.953	0.05 -16.58	3.431

Sound the ranges of temperature corresponding to the low and high salinity ranges were 28.7-31.4°C and 27.0-32.5°C respectively. Average biomass values of plankton of Daman Ganga estuary during higher salinity ranges and at almost identical temperature ranges were three times less compared to Mississippi Sound. The results of the present study and those of Mississippi Sound clearly show that the greater the amplitude of variation of salinity the greater is the range of variation of dry weights of plankton.

TABLE 4

NUMBERS OF PHYTOPLANKTON AND COPEPODS OF DAMAN GANGA ESTUARY DURING 1968-'69

Month & Year	Phytoplankton/ 5 Minutes Thousands Range	Average	Copepods/5 Minutes Thousands Range	Average
Nov. 1968	0.355-2.89	0.649	0.219-18.88	4.344
Dec.	3.465-138158.82	34539.7	0.201- 8.25	2.395
Jan. 1969	2.964-317.2	76.147	0.704-7.106	3.309
Feb.	0.256-2.75	1.059	0.011-5.915	1.537
Mar.	0.14 -16.0	5.958	0.105-12.0	2.421
Apr.	10.14-473.0	121.78	0.003-2.262	1.149
May	519.0-3561.2	1567.8	5.632-74.75	34.955
Jun.	0.0 -0.23	0.057	0.003-12.42	3.676
Jul.	0.0 -0.466	0.093	0.288- 2.1	0.477
Aug.	0.0 -0.064	0.016	0.084-0.194	0.069
Sep.	1.761-1229.85	246.79	0.566-362.5	72.798
Oct.	0.708-4.833	2.508	0.134-80.0	21.206

The winter (October to March) biomass of plankton (0.817 gm for 5 minutes per collection) of this estuary was 2.3 times higher compared to the summer (April to September) biomass of plankton (0.35 gm for 5 minutes per collection). The temperature ranges of winter and summer were 22.0.-31.8°C and 26.6-33.2°C respectively. The low summer values of biomass of plankton were associated with very low salinity range of 0.36-8.52‰ during July, August and September. In order to eliminate the low salinity factor, the biomass of plankton for summer was calculated for the period April, May and June and compared with the winter values. The summer value under comparable salinity conditions was 0.684 gm for 5 minutes per collection. Thus, the low values of biomass of plankton of this estuary were associated with low salinity and high temperature ranges of July, August and September. The average value for summer after eliminating the low salinity factor (0.684 gm for 5 minutes per collection) was still lower than the winter value (0.817 gm for 5 minutes per collection). The low summer values may be partly due to higher ranges of temperatures (26.6-33.2°C) of summer. It is well known that the higher temperatures enhance the respiratory rates of organisms and cause greater loss of energy (Sitaramaiah 1967b & 1966a).

TABLE 5

YOUNG AND ADULT FISHES CONTAINED IN THE PLANKTON COLLECTIONS OF DAMAN GANGA ESTUARY DURING 1968-'69

Species	Size Range in cm Total length	Total number
Hilsa ilisha	0.3-4.8	70
Engraulis dussumieri	0.3-6.4	156
Scianid fish larvae	0.2-1.2	99
Gobid fish larvae	0.5-2.1	8
Leptocephali larvae of eels	2.9-3.3	8
Syngnathus spicifer	5.5	1
Belone strongylurus	21.6	1
Fish eggs		1268
Crustacea		
Palaemon lamarrii		7
Post larval shrimps		68

The total number of young and adult fishes and prawns contained in the plankton collections are represented in Table 5. Inspite of the fact that the tow net is not the proper net to collect fish and fish larvae, considerable number of young, adult fishes and prawns were collected in the tow net which was operated only in the surface layer of half metre of water column. The total number of fish eggs contained in the

plankton collections was 1268. Of the 1268 fish eggs collected during the year 96 per cent were collected during the period November, 1968 to April, 1969. The occurrence of the fish eggs in the plankton collections clearly indicates that the fishes spawn either in the estuary or in the vicinity of this estuary. A plankton calendar was prepared for this estuary and is presented in Table 6.

TABLE 6

PLANKTON CALENDAR OF DAMAN GANGA ESTUARY FOR THE YEAR 1968-'69

NAME	N	D	J	F	M	A	M	J	J	A	S	O
1. *Spirogyra*	—	—	—	—	—	—	—	—	—	—	A	—
2. Cladocera	—	—	—	—	—	—	—	—	—	R	—	—
3. *Palaemon lamarrii*	—	—	—	—	—	—	—	—	R	R	—	R
4. *Synedra*	—	A	—	—	—	—	—	—	—	—	—	—
5. *Nitzchia*	—	A	—	—	—	—	—	—	—	—	—	—
6. *Cylendrotheca gracilis*	—	B	A	—	—	—	—	—	—	—	—	—
7. *Coscinodiscus*	C	A	A	C	A	B	B	R	R	R	B	A
8. Copepods	A	A	A	A	A	A	A	A	C	R	A	A
9. Crustacean eggs	—	—	—	C	—	—	—	—	—	—	—	A
10. Nauplius larvae	—	—	C	R	A	—	—	—	—	—	—	—
11. Metanauplius larvae	C	R	—	R	—	—	—	—	—	—	—	A
12. Zoea larva of prawn	R	C	C	R	A	C	—	—	—	—	—	—
13. Zoea larva of Crab	A	R	C	C	R	—	A	—	—	R	—	A
14. Megalopa larva	—	—	—	R	—	R	R	R	R	R	—	R
15. Mysidacea	R	C	C	A	A	C	A	A	R	—	R	A
16. Post larval shrimps	—	R	R	R	R	R	R	R	—	—	—	—
17. Chaetognatha	—	R	R	R	R	R	C	R	—	—	R	R
18. Fish eggs	R	R	R	R	R	R	R	R	—	R	—	R
19. *Hilsa ilisha*	R	—	—	—	—	—	—	—	R	—	—	R
20. *Engraulis dussumieri*	—	R	R	R	R	R	R	R	R	—	—	—
21. *Belone strongylurus*	—	—	—	—	—	—	—	—	R	—	—	—
22. *Syngnathus spicifer*	—	—	—	R	—	—	—	—	—	—	—	—
23. Leptocephali larvae of eels	—	—	—	—	—	—	—	—	R	—	R	—
24. Gobid fishes	—	—	—	—	—	—	—	R	R	—	—	—
25. Scianid larvae	R	R	R	—	R	—	R	R	R	—	—	R
26. Coelenterate medusae	—	—	R	R	C	R	R	R	—	—	—	—
27. *Beroe cucumis*	R	R	R	R	R	R	—	—	—	—	—	—
28. *Pleurobrachia*	—	R	R	—	R	R	—	—	—	—	—	—
29. *Salpa*	—	R	R	—	—	R	R	—	—	—	—	—
30. *Doliolum*	R	R	R	—	R	—	—	—	—	—	—	—

Rare : R : 1-100/5 minutes
Common : C : 101-1000/5 minutes
Abundant : A : 1001-100,000/5 minutes
Swarms : S : Above 100,000/5 minutes
Blooms : B :

The dry weight of biomass of plankton increased with increase in salinity (Table 7) in the estuary, towards the sea, thereby, clearly showing the existence of large sized adults of marine plankters at higher

salinities. The numbers of eggs, young ones, diatoms and copepods were more abundant in the estuarine side at lower salinities, probably because of the presence of less numbers of plankton predators like chaetognath (Table 7) which were present in more numbers in higher salinities. Thus, the rich microplankters (copepods, diatoms, crustacean eggs, zoea larvae of crabs and metanauplii) form food to the planktophagous larvae and young ones of *Hilsa ilisha* and other fishes. The major food of young *Hilsa ilisha* consists of crustacea and diatoms (Halder 1968). Excluding the sand, more than 50 per cent of the gut contents of young *Hilsa ilisha* consist of only diatoms and crustacea (Halder 1968). Furthermore, the low salinity estuarine areas could not be penetrated by the stenohaline marine plankton feeders. Thus, the euryhaline planktophagous fish larvae find more advantage in terms of abundance of food, especially, in the absence of marine stenohaline planktophagous competitors. Special ecological habitats of this nature are the natural factors that are responsible for the greater yield of west coast fisheries. Further studies are needed.

TABLE 7

DISTRIBUTION OF PLANKTON IN RELATION TO SALINITY IN DAMAN GANGA ESTUARY IN THE AREA OF CONFLUENCE ON 30-X-1969 BETWEEN 8.00 AND 13.00 HRS.

1.	Salinity ‰	20.24	27.87	29.81
2.	Dry weight of plankton: Gm/5 Minutes	0.285	0.525	0.571
3.	Crustacean eggs: Thousands/5 Minutes	4.6	—	—
4.	Fish eggs „ „	0.116	0.188	—
5.	Zoea larvae of crabs „ „	4.0	1.771	0.009
6.	Copepods „ „	452.5	350.5	106.65
7.	*Coscinodiscus* „ „	25.4	77.4	14.35
8.	Metanauplius larvae „ „	12.25	16.23	0.683
9.	Mysidacea „ „	0.602	0.293	0.004
10.	Chaetognatha „ „	0.005	0.072	0.428
11.	*Beroe cucumis* „ „	—	0.003	0.025

(4) Phytoplankton:

The numbers of phytoplankton varied from 0.016 to 34539.7 thousands for 5 minutes per collection (Table 4). Phytoplankton "Blooms" were recorded in the months of December 1968, January, April, May and September 1969. The phytoplankton maxima and submaxima were recorded in December 1968 and May 1969 respectively. Ganapati & Murthy (1956) reported two maxima one in November and the other in April in the bay of Bengal off Waltair coast. Primary maxima of phytoplankton production was reported in the east coast, in February at Waltair, in March at Madras, in June at Krusadai and in the west coast, during January to May at Trivandrum, May to September at Calicut, September to February at Bombay (Ganapati & Murthy 1956).

Subrahmanyan (1960b) recorded maximum standing crop in May-September-October attaining peak in July, minimum in November and with one or more pulses of production. In this study, the diatoms constituted the bulk of the phytoplankton. The total number of zooplankters increased with increase of diatoms. Similar observations have been made earlier (Subrahmanyan 1960b).

(5) **Copepods:**

The numbers of copepods varied from 0.069-362.5 thousands for 5 minutes per collection during November 1968 to October 1969 (Table 4). The mean monthly maxima and submaxima of copepods were recorded in September and May 1969 respectively. The results of this study showed peak numbers of copepods associated with peak numbers of phytoplankton or preceded by large numbers of phytoplankters. On 18-i-1969 a "Bloom" of phytoplankton was associated with large numbers of copepods. During May 1969 the copepods maxima was preceded by peak numbers of phytoplankton. An increase in numbers of copepods on 1-i-1969 was preceded by large numbers of phytoplankton. Thus, the general statement that the appearance of phytoplankton will be succeeded by zooplankton holds good in this estuary. Similar observations have been made earlier in the sea off Waltair coast (Ganapati & Sarma 1958).

Acknowledgements

I thank the University Grants Commission, New Delhi for the grant of financial assistance for this project. I also thank Dr. S. C. Arya, Principal of the college for giving me facilities for this work.

References

Barnes, H. (1959): Apparatus and methods of Oceanography (Chemical). George Allen & Unwin, London, p. 341.

Bose, B. B. (1956): Observations on the hydrology of the Hooghly estuary. *Indian J. Fish.* *3*:101-118.

Chacko, P. I. & Ganapati, S. V. (1949): Some observations of the Adayar river with special reference to its hydrographical conditions. *Indian-geogr. J.* *24*:1-15.

Durve, V. S. & Bal, D. V. (1961): Hydrology of Kelva backwater and adjoining sea. *J. Univ. Bombay* *29*: 39-48.

Ganapati, P. N. & Murthy, V. S. R. (1955): Preliminary observations on the hydrography and inshore plankton in the bay of Bengal off Visakhapatnam coast. *Indian J. Fish.* *2*:84-95.

——————— & ——————— (1956): Phytoplankton production in relation to depth and distance in the Bay of Bengal off the Waltair coast. *Proceedings of the eighth Pacific Science Congress*, Vol. III A, pp. 1145-1155. Oceanography and Zoology.

——————— & SARMA, D. V. (1958): Hydrography in relation to the production of plankton off Waltair coast. *Mem. Oceanogr. Andhra Univ., Ser. 62,* II:168-192.

GRAHAM, H. W. (1943): Chlorophyll content of marine plankton. *J. Mar. Res. 5*:153-160.

HALDER, D. D. (1968): Observations on the food of young *Hilsa ilisha* (Hamilton) around Nabadwip in the Hooghly estuary. *J. Bombay nat. Hist. Soc. 65*(3):796-797.

JAYARAMAN, R. & GOGATE, S. S. (1957): Salinity and temperature variations in the surface waters of the Arabian sea off the Bombay and Saurashtra coasts. *Proc. Ind. Acad. Sci.* (B) *45* (4):151-164.

MALHOTRA, J. C., MATHUR, P. K., YUSUF KAMAL, M. & MAHROTRA, S. N. (1970): Observations on the hatching of fertilized eggs of *Hilsa ilisha* (Hamilton) in confined freshwaters. *Current Sci. 39*(23):538-539.

PANIKKAR, N. K. (1950): Physiological aspects of adaptation to estuarine conditions. *Proc. Indo-Pacific Coun.,* 2nd Meeting, 168-175, Australia.

——————— & JAYARAMAN, R. (1966): Biological and Oceanographic differences between the Arabian Sea and the Bay of Bengal as observed from the Indian region. *Proc. Ind. Acad. Sci.* (B) *64*(5):231-240.

QASIM, S. Z., WELLERSHAUS S., BHATTATHIRI P. M. A. & ABIDI, S. A. H. (1969): Organic production in a tropical estuary. *Proc. Ind. Acad. Sci.* (B) *69*(2):51-94.

RAMAMOORTHY, S. (1953): Hydrobiological studies in Madras coastal waters. *J. Madras Univ.* (B), *23*:148-163.

SITARAMAIAH, P. (1966a): Studies on growth rates of some freshwater animals. *J. Anim. Morph. Physiol. 13* (1 & 2): 103-113.

——————— (1966b): Studies on the ecology of a freshwater pond community. *Hydrobiologia 27*(3-4): 529-547.

——————— (1967a): On the fertility of the Mississippi Sound. *Proc. Zool. Soc.* Calcutta, *20*:39-42.

——————— (1967b): Community metabolism in a tropical freshwater pond. *Hydrobiologia 29* (1-2): 93-112.

SUBRAHMANYAN, R. (1960a): Studies on the phytoplankton of the west coast of India. Part II. Physical and chemical factors influencing the productivity of phytoplankton with remarks on the cycle of nutrients and on the relationship of the phosphate content to fish landings. *Proc. Ind. Acad. Sci.* (B) *50*:189-252.

——————— (1960b): Studies on the Phytoplankton of the west coast of India. Part I. Quantitative and qualitative fluctuations of the total phytoplankton crop, the zooplankton crop and their inter-relationship with remarks on the magnitude of the standing crop and production of matter and their relationship to fish landings. *Proc. Ind. Acad. Sci.* (B) *50* (3):113-187.